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The Effect of High Load Training on Psychomotor Speed

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Key words

- overreaching
- overtraining
- reaction time

Abstract

▼ The purpose of the present study was to investigate whether overreached athletes show psychomotor slowness after a period of high load training. Fourteen well-trained cyclists (10 male, 4 female, mean age 25.3 [SD = 4.1] years, mean maximal oxygen consumption 65.5 [SD = 8.1] ml/kg·min) performed a maximal graded exercise test on a cycle ergometer, filled out two questionnaires and performed two tests of psychomotor speed before and after high load training and after two weeks of recovery training. A control group performed the two tests of psychomotor speed on the same occasions without changing

physical activity levels. Five cyclists were classified as functional overreached, seven cyclists were classified as well-trained and two cyclists were excluded from analysis. Results showed no significant differences in psychomotor speed between the control, well-trained and functional overreached groups on the three measurements. A trend towards psychomotor slowness was found for the functional overreached compared to the control group after high load training. Additional research with more subjects and a greater degree of overload training is necessary to more conclusively determine if psychomotor speed can be used as an early marker for overtraining.

Introduction

▼ To reach the top in sports it is necessary to perform high training loads. In cycling a minimum of 30 000 km a year is required to perform at the highest level [5]. Commonly, weeks with high and low training loads are applied alternately [25]. Training camps are a common part of this highly demanding athletic training. Training loads are increased during training camps with the goal to improve performance after a period of regeneration. Immediately after the period of overload training performance will usually be impaired; the athlete is overreached [e.g., 4,8,10,27,30]. As the athlete recovers and returns to or improves pre-overload performance levels, this specific state is called functional overreaching (FO) [17,21]. However, a period of overload training does not always lead to increased performance. If, after a recovery period of two weeks an athlete is still not recovered, he or she is in a state of non-functional overreaching (NFO). FO and NFO should be distinguished from overtraining syndrome (OTS) based on the severity of the symptoms and on the recovery period that is

needed. Only in OTS pathophysiological symptoms, such as depression, fatigue, eating, sleeping and concentration problems and hormonal deviations, will reach clinical levels [e.g., 16,18,31]. Although these symptoms can be present in FO and NFO as well, the symptoms will be less severe. Another difference between the three conditions is the recovery period needed. Recovery from OTS takes months up to years whereas recovery from NFO takes weeks up to a few months. By definition, recovery from FO takes less than a few weeks [17,21].

A lot of research has been devoted to the early detection of OTS. The monitoring of physiological variables as heart rate, oxygen uptake, blood lactate, but also hormonal, immunological and biochemical markers has received most attention. Although large progress has been made, this kind of research has so far not lead to a useable tool for early detection of overtraining [9,29]. One of the problems with these kinds of markers is related to the costs of regular assessment needed for reliable monitoring of athletes. Subjective measures do not have this disadvantage and seem promising as markers for OTS. Especially the Pro-

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Bibliography

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file of Mood States (POMS) has frequently been studied. Although not designed for use in athletic settings, it has shown to be a useful marker for overtraining [15,23]. However, a potential problem with the use of subjective markers is the manipulability of (daily) questionnaires. This could be a problem especially in team sports.

Thus, there is still a need for a reliable, affordable and useable marker. It is hypothesized that psychomotor speed might be such a marker [21]. This hypothesis is based on the similarities between OTS on the one hand and major depression and chronic fatigue syndrome on the other hand [3,7,24] and on the fact that psychomotor speed is consistently reduced in both syndromes [19,28,32]. A theoretical clue for this hypothesis has been given by Lehmann et al. [14] by stating that central fatigue associated with disturbances in perception, coordination and concentration occurs in overtraining. These disturbances can possibly be assessed by tasks of psychomotor speed. The advantage of psychomotor speed over other markers is the fact that it can easily be obtained in training practice because assessment is affordable and not demanding. Additionally, the measurement of psychomotor speed is inexpensive and objective.

Some support for the psychomotor slowness hypothesis has already been found. Andersen and Williams [2] found that stress influenced athletes' performance on neuropsychological tasks in stressful conditions compared to neutral conditions. Specifically, peripheral vision narrowed under stress and was found to be significantly related to the number of injuries athletes experienced [2]. More specific support has been found by Rietjens and colleagues, who found that cyclists performed worse on the two most difficult conditions of a test of selective attention than a control group after a two week period of increased training loads [23]. They did not find any differences on performance, physiological, hormonal or blood variables.

Assessing athletes during high load training has frequently been used for studying overreaching. For the evaluation of overreaching state it is necessary to test the performance capacity of the athletes. Without performance decrements overreaching or overtraining does not exist [9]. This has not always been done and in some studies performance evaluation has taken place in a group based manner. However, for the assessment of training status an individual approach is necessary.

Indeed, many authors have used individual criteria for the classification of athletes as overreached or well-trained [4,8,11,26,30]. However, a total of 12 different criteria have been identified in these studies. Although at least one criterion includes performance measures in all studies, in one study a stagnation in performance is seen as a sign of overreaching [11], in the other four studies a reduction in performance is required [4,8,26,30]. However, in only one report a detailed description of what is regarded a reduction in performance is found [26]. All authors combine performance criteria with subjective ratings of fatigue and/or mood changes, but again 5 different measures have been used. In other words, there is not much consensus about the individual criteria that should be used to identify overreached athletes. Halson et al. [8] argued, deteriorations in performance should be accompanied by mood disturbances to be able to speak of overreaching. Thus, objective criteria should conditionally be accompanied by a subjective marker.

In the present study a combination of objective, well defined markers will be used in combination with a subjective marker to classify the athletes. The purpose of the present study is to test the psychomotor slowness hypothesis studying the effects

of high load training. It is hypothesized that athletes with FO show psychomotor slowness compared to healthy athletes.

Materials and Methods



Subjects

Fourteen well-trained male ($n = 10$) and female ($n = 4$) cyclists and fourteen control subjects (9 male, 5 female) completed the study. The mean age was 25.3 ($SD = 4.1$) for the cyclists and 25.4 ($SD = 4.6$) for the control subjects. Mean education level was 4.6 ($SD = .5$) on a 5 point scale for both the training camp and the control group. The cyclists trained 13.4 hours a week ($SD = 4.3$) while the control subjects trained 5.6 hours a week ($SD = 2.7$). The cyclists had a mean length of 181.2 cm ($SD = 8.7$) and a mean weight of 73.1 kg ($SD = 9.1$). Their mean maximal oxygen uptake was 65.6 ml/kg·min⁻¹ ($SD = 8.1$), their mean maximal workload was 4.9 W/kg ($SD = .6$). The cyclists had a mean training history of 8.0 years ($SD = 3.8$) and performed at their present level for an average of 2.5 years ($SD = 1.4$). The mean amount of racing days was 37 ($SD = 16$) per year.

Experimental design

The study was conducted according to the Declaration of Helsinki for Medical Research involving Human Subjects and was approved by the Medical Ethical Committee of the University Medical Center Groningen. Informed consent was obtained from each subject before starting participation in the study. The high load training period consisted of a regular training camp during which the cyclists performed their own training schedule. The training camp lasted on average 9.5 days ($SD = 2.8$). Participation in the study lasted from two weeks before the training camp (baseline training) until two weeks after (recovery training). Cyclists started with filling out a training log during baseline training and continued doing this until the end of recovery training. They completed a nutrition log twice during three consecutive days, once during high load training and once during recovery training. One or two days before the start of their training camp cyclists came to our lab for performance assessment, assessment of mood state and for reaction time assessment.

The day after the cyclists returned from their training camp they came to our lab for the second performance, reaction time and questionnaire assessment. After two weeks of recovery training they came to our lab for the third assessment.

The control group performed the reaction time tests three times with the same time intervals as the cyclists. The control subjects did not change their weekly exercise loads during the study.

Measures

Training log

In the training log type of training, training distance (km), training duration (min), and session rate of perceived exertion (session RPE) were reported by the athletes after every training. Perceived recovery, resting heart rate, and whether any injury or illness was present were reported by the athletes every day. Session RPE and perceived recovery were reported on adjusted 6–20 Borg scales with 6 = “not strenuous at all”/“not recovered at all” and 20 = “maximal strenuous”/“totally recovered”. Resting heart rate was measured by hand every morning before getting up.

Training load and monotony were calculated according to the methods presented by Foster [6]. Training duration was multi-

plied by session RPE to obtain the load for each training session. Training load of each period (i.e., baseline training, high load training and recovery training) was calculated by summing up the load of all training sessions of that period divided by the amount of days of that period. Training monotony was calculated by dividing the training load by the standard deviation of each period.

Nutrition log

During three executive days the cyclists completed a nutrition log in which they reported the sort of food and drinks they consumed and the quantity. Nutritional values (carbohydrates, proteins and fats) of the diet were calculated for each cyclist during high load training and during recovery training.

Recovery stress questionnaire for athletes (RESTQ-sport)

A Dutch translation of the RESTQ-sport was used to assess the frequency and direction of perceived general and sport specific stress and of perceived general and sport specific regeneration activities [12]. Questions are answered on a 7 point Likert-type scale with 0 = "never" and 6 = "always". The RESTQ-sport consists of 19 scales of which 7 scales that assess general stress, 5 scales assess general recovery, 3 scales assess sport specific stress, and 4 scales assess sport specific recovery. Each scale consists of 4 questions. The RESTQ-sport has sufficient reliability and validity [12].

Profile of mood states (POMS)

In the present study the Dutch version of the POMS was used to measure mood states. The Dutch POMS consists of 5 scales with a total of 32 items that assess the negative moods depression (8 items), anger (7 items), fatigue (6 items), and tension (6 items) and the positive mood vigour (5 items). The Dutch POMS has sufficient reliability and validity [33].

Finger pre-cuing task

The finger pre-cuing task is a test of psychomotor speed [1,20]. Plus (+) signs are presented as stimuli on a standard monitor controlled by a personal computer. The stimulus display consisted of a warning signal, a cue signal, and a target signal centered on the monitor. The response was given by pressing one of four keys of the keyboard ("z", "x", "." or "/") with the index and middle fingers of both hands. The warning signal consisted of a row of four plus signs. After a delay of 750 ms the cue signal appeared below the warning signal. The cue signal consisted of two plus signs either below the middle or outer two plus signs (finger-cued condition), below the two leftmost or the two rightmost plus signs (hand-cued condition), or below the rightmost and left of the middle or the leftmost and right of the middle plus signs (neither-cued condition), or the cue signal consisted of four plus signs below the warning signal (un-cued condition). After a time interval of 500 ms the target signal appeared below the cue row always on a position indicated by the cue. The subject's task was to respond as quickly as possible to the target signal by pressing the appropriate key. There were 40 trials for each condition (10 for each of the four stimulus positions) given in a random order in a block of 160 trials. Ten practice trials preceded the block of 160 trials.

Median reaction time was calculated for each subject per test and per pre-cuing condition. Incorrect responses as well as reaction times shorter than 150 ms or longer than 1.5 s were omitted in the calculation of median reaction time.

Determination test

The Determination Test, performed on the Vienna Test System (Schuhfried, Moedling, Austria), is a reaction time test with five different visual stimuli to which a manual reaction is required, two visual stimuli to which a pedal reaction is required and one auditory stimulus to which again a manual reaction is required. The Determination Test consists of two parts. In the first part, the action mode, a new stimulus occurs as soon as a correct reaction is given. This part lasts 5 minutes. In the second part, the reaction mode, two visual/manual stimuli should be inhibited. The stimuli occur in six blocks with pre-set presentation times of 1.225, 0.948, 0.834, 0.734, 0.646 and 0.834 s. The reaction mode consists of a total of 360 stimuli. Median reaction times were calculated for each subject at each measurement for the action mode and the reaction mode and for the six subsequent presentation intervals of the reaction mode separately. Only correct, on time responses were used in the calculation of median reaction time.

Exercise testing

An incremental graded maximal exercise test was performed by the cyclists on an electrically braked bicycle ergometer (Lode Excalibur Sport, Groningen, The Netherlands). The exercise test was preceded by a warming-up of three minutes at 80 W for the males and 60 W for the females. For males the initial test workload was 160 W, the workload was increased every 3 min by 40 W until volitional exhaustion. Females started the test at 120 W with an increase in workload of 30 W every 3 min until volitional exhaustion. In the last 30 sec of every workload heart rate was measured and oxygen consumption was analyzed breath by breath (Jaeger Oxycon Delta, Hoechberg, Germany).

To assess whether athletes were overreached or well-trained after the period of high load training a combination of objective and subjective criteria was used. Two out of three following objective criteria should be fulfilled a) a 10 W or more decrease in maximal load, b) a 5 bpm or more decrease in maximal heart rate or c) a reduction of 200 ml/min or more in maximal oxygen uptake. And one of the following subjective criteria should be fulfilled 1) a mood disturbance as measured with the POMS or 2) a disturbance in perceived stress and recovery as measured with the RESTQ-sport. Athletes fulfilling one subjective and two objective criteria at the second but not at the third test were classified as FO, athletes not fulfilling these criteria were classified as well-trained.

Statistical analysis

All results were reported as significant at $p < .05$. All results were analyzed using ANOVA or MANOVA with group as a between subjects factor and time as a within subjects factor. Gender and age were not entered into the equations, because the groups were matched for these variables. In case of the FPT pre-cuing condition was entered as a second within subjects factor. If Mauchly's test of sphericity indicated that the assumption of sphericity was violated, the degrees of freedom were corrected using Huynh-Feldt estimates.

Results



Five athletes fulfilled the criteria of FO (i.e. they fulfilled at least two out of the three objective criteria in combination with at least one subjective criterion during the second but not during

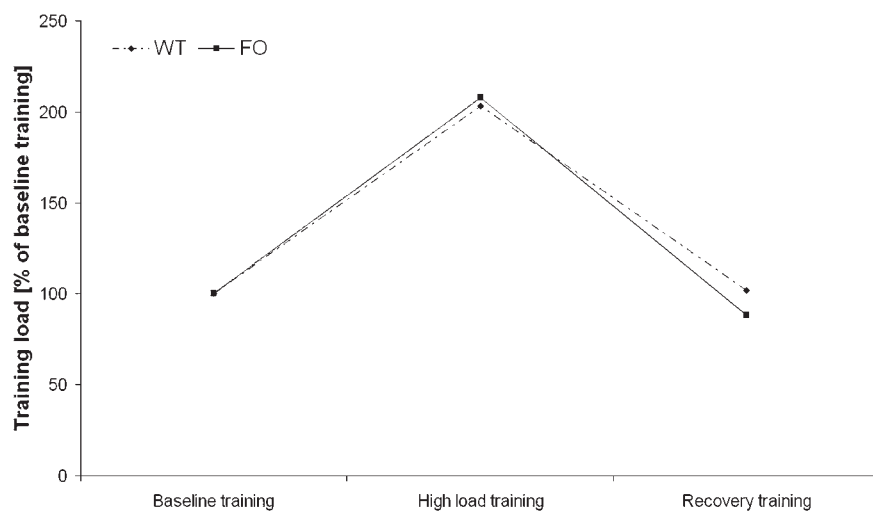


Fig. 1 Average training loads during baseline, high load and recovery training for the well-trained (WT) and the functional overreached (FO) groups in percentages of baseline training.

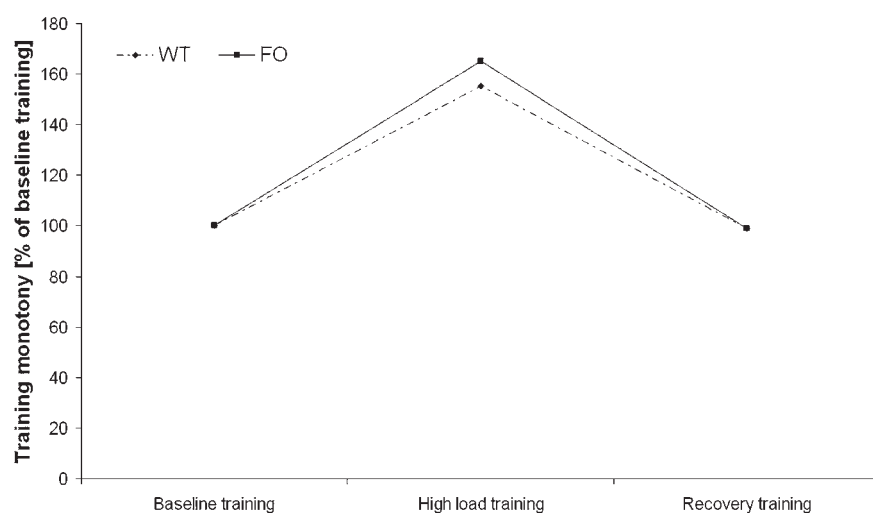


Fig. 2 Average training monotony during baseline, high load and recovery training for the well-trained (WT) and the functional overreached (FO) groups in percentages of baseline training.

the third exercise test). Two athletes showed very high perceived general stress and low perceived general recovery in the RESTQ-sport in combination with unfavorable mood state scores on the POMS before the training camp. After the training camp they showed much more favorable scores on both the RESTQ-sport and the POMS. One of these athletes showed worse scores again after recovery training. Because the training camp seemed to have the opposite effect for these athletes (i.e. they showed a more positive stress recovery balance after high load training than during everyday life), these two athletes were excluded from further analyses. The other seven athletes were classified as well-trained (WT) because they did not fulfill the criteria for overreaching after the training camp.

Training variables

Training load and monotony were set at 100% during baseline training. Load and monotony during high load and recovery training were expressed as percentages of baseline training. Training load and monotony were analyzed using MANOVA. Significant main effects of time were found for both training load and monotony ($F[2,18] = 32.89$ and $F[1.3,18] = 13.81$, respectively). Polynomial contrasts showed a quadratic effect of time for both variables ($F[1,9] = 47.65$, $r = .92$ and $F[1,9] = 15.67$, $r = .80$, respectively). **Fig. 1** shows that the training load was twice as

high during high load training compared to baseline training. During recovery training, training loads were somewhat lower compared to baseline for both groups. **Fig. 2** shows that also training monotony was higher during high load training compared to baseline and recovery training. No main effect for group was found nor any interaction effects.

Nutrition

Carbohydrate intake and total caloric intake were analyzed using a MANOVA. A main effect for time was found for carbohydrate and total caloric intake ($F[1,10] = 32.86$ and $F[1,10] = 39.34$, respectively). Contrasts showed that both caloric and carbohydrate intake were higher during compared to outside the training camp ($F[1,12] = 27.63$, $r = .83$ for total caloric intake and $F[1,12] = 22.36$, $r = .80$ for carbohydrate intake). No main effect for group was found nor any interaction effects.

Finger pre-cuing task

Scores on the finger pre-cuing task for the three different groups (control, WT and FO) were tested for significance using an ANOVA for repeated measures at three different times (baseline training, high load training and recovery training) for the four conditions (un-cued, finger-cued, hand-cued and neither-cued). Scores on the finger pre-cuing task can be found in **Table 1**. Significant

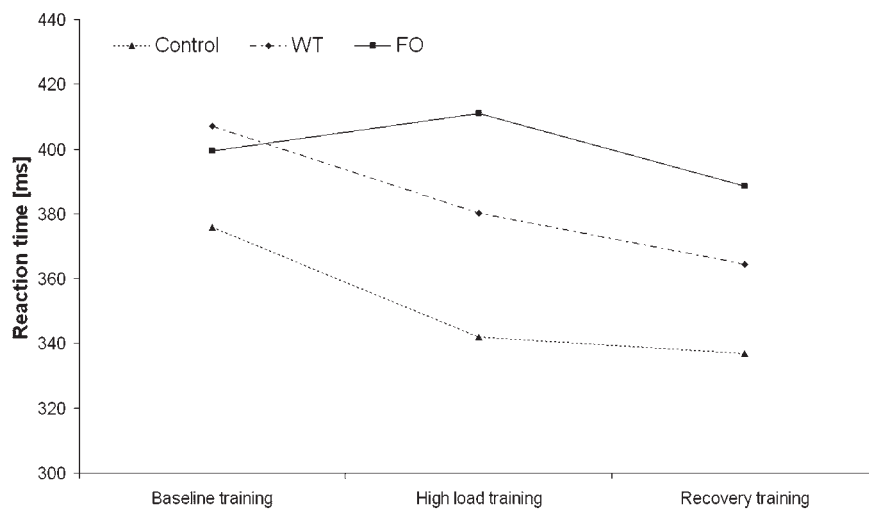


Fig. 3 Mean reaction times averaged over all conditions on the finger pre-cuing task after baseline, high load and recovery training for the control, well-trained (WT) and functional overreached (FO) groups.

Table 1 Reaction times for the four conditions of the finger pre-cuing test for the three groups after baseline, high load and recovery training

Condition	Baseline training			High load training			Recovery training		
	Control	WT	FO	Control	WT	FO	Control	WT	FO
Un-cued	399 ± 69	429 ± 70	426 ± 35	370 ± 55	401 ± 64	440 ± 74	364 ± 54	392 ± 49	416 ± 38
Hand-cued	351 ± 73	380 ± 68	361 ± 42	321 ± 58	359 ± 58	368 ± 65	319 ± 54	336 ± 43	350 ± 43
Finger-cued	372 ± 94	404 ± 77	400 ± 34	331 ± 80	382 ± 73	406 ± 62	327 ± 66	361 ± 49	383 ± 45
Neither-cued	379 ± 88	414 ± 77	410 ± 41	347 ± 83	377 ± 69	429 ± 70	338 ± 65	368 ± 57	406 ± 54

Results are expressed as means ± standard deviations. WT = well trained cyclists, FO = functional overreached cyclists.

main effects were found for time ($F[1.86, 42.68] = 11.31$) and condition ($F[2.38, 54.73] = 64.16$). Polynomial contrasts showed a linear improvement of performance on the finger pre-cuing task over time ($F[1, 23] = 17.50$, $r = .66$). Simple contrasts showed significant differences between all cued conditions compared to the un-cued condition of the finger pre-cuing task ($F[1, 23] = 465.47$, $r = .98$ for the finger-cued, $F[1, 23] = 40.68$, $r = .80$ for the hand-cued and $F[1, 23] = 21.33$, $r = .69$ for the neither-cued condition) with the longest reaction times for the un-cued condition. No significant main effect was found for group.

None of the interaction effects showed significant differences. However, two interaction effects came close to significance. The interaction between time and group approached significance with $p = .079$ ($F[3.71, 42.68] = 2.30$). From **Fig. 3** it becomes clear that the largest difference can be found between the FO and the control group at the second measurement, thus after high load training. The interaction effect between condition and group also approached significance with $p = .083$ ($F[4.76, 54.73] = 2.10$). **Fig. 4** shows that the difference between the FO and the control group is smaller in the hand cued condition compared to the other more difficult conditions.

Determination test

The action and the reaction mode of the determination test were analyzed separately. The action mode was analyzed using an ANOVA for repeated measures with three measurements (baseline training, high load training and recovery training) and three groups (control, WT and FO). A significant main effect for time was found ($F[1.69, 38.91] = 129.10$). Polynomial contrasts revealed a linear improvement over time ($F[1, 23] = 219.66$, $r = .95$). The main effect of group and the interaction between time and group were not significant.

Reaction times of the reaction mode were also analyzed using an ANOVA for repeated measures for the three measurements (baseline training, high load training and recovery training) and for the six presentation intervals (1.225, 0.948, 0.834, 0.734, 0.646 and 0.834 s). Significant main effects were found for time ($F[1.73, 39.67] = 96.25$) and presentation interval ($F[4.35, 100.08] = 13.55$). Polynomial contrasts showed a linear improvement of performance on the determination test over time ($F[1, 23] = 156.85$, $r = .93$). Also for presentation interval polynomial contrasts showed a linear improvement ($F[1, 23] = 45.43$, $r = .81$) with faster reaction times for shorter presentation intervals. The effect of group was not significant, nor were any of the interaction effects.

Although not significant, an interesting finding is the interaction between group and presentation interval (**Fig. 5**). The control group shows no increases in reaction times by faster presentation intervals, whereas both training camp groups show increased reaction times for the two fastest presentation intervals. These are the conditions in which the presentation interval is as long as or shorter than the subjects' reaction time in easy conditions (i.e., when self paced in the action mode or in the conditions with the longest presentation interval when automatically paced).

Discussion

The main purpose of the present study was to study whether psychomotor speed is affected by high load training. Specifically, it was hypothesized that FO athletes would perform worse on two tasks of psychomotor speed than WT athletes. Five out of 14 athletes who participated in the study were FO after their

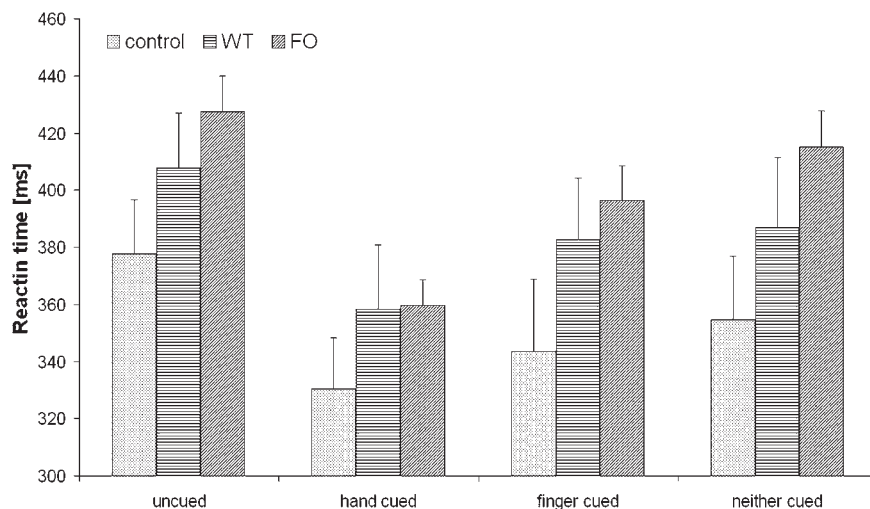


Fig. 4 Mean reaction times on the un-cued, hand-cued, finger-cued and neither-cued conditions of the finger pre-cuing task for the control, well-trained (WT) and functional overreached (FO) groups averaged over the three measurements.

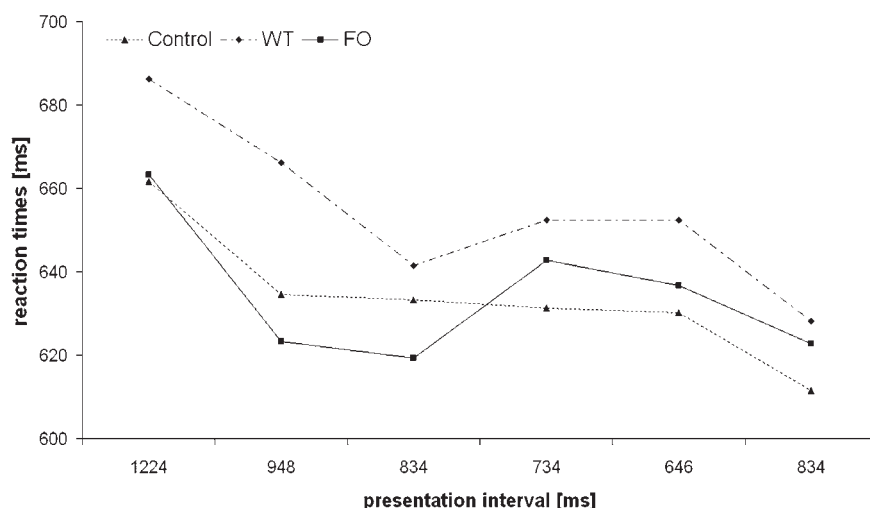


Fig. 5 Mean reaction times for the different presentation intervals on the Determination Test for the control, well trained (WT) and functional overreached (FO) groups averaged over the three measurements.

training camp, seven athletes were classified WT and two athletes were excluded from the analyses because they showed a disturbed stress-recovery balance already before the training camp.

Significant main effects were found on the finger pre-cuing task for time and for condition. Subjects usually become faster as they repeatedly perform reaction time tasks. This is exactly what was found in the present study. The effect of condition can be explained by the difficulty of the condition. The pre-cued conditions are easier than the un-cued condition because these are two choice reaction time conditions while the un-cued condition is a four choice reaction time condition [1]. The hand-cued condition is the easiest pre-cued condition which indeed gave the shortest reaction times in the present study. The hand-cued condition is followed by the finger-cued condition and the neither-cued condition is the most difficult pre-cued condition. In the present study reaction times were indeed longer as the condition became more difficult.

The interaction effect between time and group showed a trend towards significance. The FO group was slower than the control group on the second measurement, thus after high load training (see ● Fig. 3). Reaction times of the FO group increased 11 ms (performance decrement) from baseline training to high load training, whereas reaction times of the WT and the control group

decreased 27 and 34 ms respectively (increase in performance). After high load training the FO group was 20% slower than the control group and 8% slower than the WT group. For comparison, patients with major depression are 20 to 26% slower than healthy controls [21,32] and patients with chronic fatigue syndrome are 15% slower than healthy controls [21]. Thus, although not statistically significant, differences in the present study are meaningful.

The fact that a trend towards psychomotor slowness has been found instead of statistical differences might have been caused by the small sample size for a repeated measures design with three measurements. This was due to the fact that only 5 out of 14 cyclists were FO after high load training. In future studies a heavier and/or a longer training protocol should ensure more FO subjects after high load training. Additionally, the fact that the symptoms are mild and of short duration might have influenced the degree of psychomotor slowness. Future studies should explore the degree of psychomotor slowness in NFO and OTS athletes.

The interaction between group and condition also approached significance. ● Fig. 4 shows that the easiest condition (i.e. the hand cued condition) gave smaller differences between the FO and the control group than the more difficult conditions. Rietjens et al. [23] also found differences on the most difficult condi-

tions of the finger pre-cuing task between a high load training group and a control group.

On the determination test a main effect was found for time and for presentation interval in the reaction mode. The main effect of time represents the same practice effect as was found on the finger pre-cuing task. Practice effects are regarded very general effects. Therefore, it is not surprising that a practice effect was found in the present study as well. The significant linear effect of presentation interval showed that subjects react faster as the pressure becomes higher. No significant group differences were found on the determination test, although a marked difference can be observed between the three groups on the reaction mode (● Fig. 5). Both the FO and the WT group showed an increase in reaction time when put under pressure. This result is similar to earlier results [2, 22]. It seems that athletes are not able anymore to optimally perform under pressure when they experience a less favorable stress recovery balance. Athletes who overtrain or overreach have a less favorable stress recovery balance [13]. However, the athletes in the present study did not experience negative consequences of this disbalance on the long run which might have been the reason that differences were not significant. In conclusion, the direction of the trends found in the present study are consistent with theory and hypotheses. Task characteristics such as task difficulty and the amount of stress within a task should be manipulated in future studies. Results on the determination test suggest that athletes under high stress perform less in stressful task conditions compared to controls. Also, task difficulty seems to be a factor that can influence psychomotor speed in overreached and maybe overtrained athletes as is suggested by the results on the finger pre-cuing task. Further, more research should be conducted, especially in more severe overtraining states (e.g., NFO and OTS) to conclude whether psychomotor slowness exists in overtrained athletes and could therefore be an early marker for OTS.

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Reference

- Adam JJ, Hommel B, Umiltà C. Preparing for perception and action (I): The role of grouping in the response-cuing paradigm. *Cogn Psychol* 2003; 46: 302–358
- Andersen MB, Williams JM. Athletic injury, psychosocial factors and perceptual changes during stress. *J Sports Sci* 1999; 17: 735–741
- Armstrong LE, VanHeest JL. The unknown mechanism of the overtraining syndrome: clues from depression and psychoneuroimmunology. *Sports Med* 2002; 32: 185–209
- Bosquet L, Leger L, Legros P. Blood lactate response to overtraining in male endurance athletes. *Eur J Appl Physiol* 2001; 84: 107–114
- Fernandez-García B, Perez-Landaluce J, Rodriguez-Alonso M, Terrados N. Intensity of exercise during road race pro-cycling competition. *Med Sci Sports Exerc* 2000; 32: 1002–1006
- Foster C. Monitoring training in athletes with reference to overtraining syndrome. *Med Sci Sports Exerc* 1998; 30: 1164–1168
- Fry RW, Morton AR, Keast D. Overtraining syndrome and the chronic fatigue syndrome: Part 1. *N Z J Sports Med* 1991; 19: 48–52
- Halsen SL, Bridge MW, Meeusen R, Busschaert B, Gleeson M, Jones DA et al. Time course of performance changes and fatigue markers during intensified training in trained cyclists. *J Appl Physiol* 2002; 93: 947–956
- Halsen SL, Jeukendrup AE. Does overtraining exist? An analysis of overreaching and overtraining research. *Sports Med* 2004; 34: 967–981
- Hedelin R, Kentta G, Wiklund U, Bjerle P, Henriksson-Larsen K. Short-term overtraining: effects on performance, circulatory responses, and heart rate variability. *Med Sci Sports Exerc* 2000; 32: 1480–1484
- Hooper SL, Mackinnon LT, Howard A, Gordon RD, Bachmann AW. Markers for monitoring overtraining and recovery. *Med Sci Sports Exerc* 1995; 27: 106–112
- Kellmann M, Kallus KW. Recovery-stress Questionnaire for Athletes: User Manual. Champaign, IL: Human Kinetics, 2001
- Kenttä G, Hassmén P. Overtraining and recovery. A conceptual model. *Sports Med* 1998; 26: 1–16
- Lehmann M, Foster C, Keul J. Overtraining in endurance athletes: a brief review. *Med Sci Sports Exerc* 1993; 25: 854–862
- Martin DT, Andersen MB, Gates W. Using Profile of Mood States (POMS) to monitor high-intensity training in cyclists: Group versus case studies. *Sport Psychologist* 2000; 14: 138–156
- Meehan HL, Bull SJ, Wood DM, James DVB. The overtraining syndrome: A multicontextual assessment. *Sport Psychologist* 2004; 18: 154–171
- Meeusen R, Duclos M, Gleeson M, Steinacker J, Rietjens G, Urhausen A. Prevention, diagnosis and treatment of the overtraining syndrome. *Eur J Sport Sci* 2006; 6: 1–14
- Meeusen R, Piacentini MF, Busschaert B, Buysse L, Schutter Gd, Stray-Gundersen J. Hormonal responses in athletes: the use of a two bout exercise protocol to detect subtle differences in (over)training status. *Eur J Appl Physiol* 2004; 91: 140–146
- Michiels V, Cluydts R. Neuropsychological functioning in chronic fatigue syndrome: a review. *Acta Psychiatr Scand* 2001; 103: 84–93
- Miller J. Discrete versus continuous stage models of human information processing: In search of partial output. *J Exp Psychol: Human Percept Perf* 1982; 8: 273–296
- Nederhof E, Lemmink KAPM, Visscher C, Meeusen R, Mulder T. Psychomotor speed: Possibly a new marker for overtraining syndrome. *Sports Med* 2006; 36: 817–828
- Nederhof E, Lemmink KAPM, Zwerver J, Meeusen R. Psychomotor speed is a possible marker for overreaching. Abstract Book of the 10th Annual Congress of the ECSS; 2005, July 13–16; Belgrade. Belgrade, Serbia: European College of Sport Science, 2005: 101
- Rietjens GJWM, Kuipers H, Adam JJ, Saris WHM, Breda Ev, Harmont Dv et al. Physiological, biochemical and psychological markers for overreaching: Early markers for overreaching. *Int J Sports Med* 2005; 26: 16–26
- Shephard RJ. Chronic fatigue syndrome: an update. *Sports Med* 2001; 31: 167–194
- Smith DJ. A framework for understanding the training process leading to elite performance. *Sports Med* 2003; 33: 1103–1126
- Snyder AC. Overtraining and glycogen depletion hypothesis. *Med Sci Sports Exerc* 1998; 30: 1146–1150
- Steinacker JM, Lormes W, Kellmann M, Liu Y, Reissnecker S, Opitz-Gress A et al. Training of junior rowers before world championships. Effects on performance, mood state and selected hormonal and metabolic responses. *J Sports Med Phys Fitness* 2000; 40: 327–335
- Tiersky LA, Johnson SK, Lange G, Natelson BH, DeLuca J. Neuropsychology of chronic fatigue syndrome: a critical review. *J Clin Exp Neuropsychol* 1997; 19: 560–586
- Urhausen A, Kindermann W. Diagnosis of overtraining: what tools do we have? *Sports Med* 2002; 32: 95–102
- Uusitalo AIT, Uusitalo AJ, Rusko HK. Exhaustive endurance training for 6–9 weeks did not induce changes in intrinsic heart rate and cardiac autonomic modulation in female athletes. *Int J Sports Med* 1998; 19: 532–540
- Uusitalo AL, Valkonen-Korhonen M, Helenis P, Vanninen E, Bergstrom KA, Kuikka JT. Abnormal serotonin reuptake in an overtrained, insomniac and depressed team athlete. *Int J Sports Med* 2004; 25: 150–153
- White DA, Myerson J, Hale S. How cognitive is psychomotor slowing in depression? Evidence from a meta-analysis. *Aging Neuropsychol Cogn* 1997; 4: 166–174
- Wicherts JM, Vorst HCM. Modelpassing van de verkorte Profile of Mood States en meetinvariantie over mannen en vrouwen. *Nederlands Tijdschrift voor de Psychologie* 2004; 59: 12–21